Boyle's Law Lab AF

Process Objectives

- To measure the volumes of gas in a container subject to varying pressures.
- To analyze the data taken in a pressure-volume experiment by plotting different curves.

Learning Objectives

- To interpret a completed pressure-volume graph.
- To gain laboratory experience with Boyle's law.

Introduction

According to Boyle's law, the volume of a fixed amount of dry gas is inversely proportional to the pressure, if the temperature remains constant. Boyle's law may be stated mathematically as $p \propto 1/V$ or $pV = k$ (where k is a constant). An understanding of Boyle's law is useful in cooking at high altitudes. If a standard sea level recipe is used to prepare a cake at an altitude of 1000 meters (3,300 feet) the cake will be flatter than expected. At the reduced barometric pressure of the high altitude, the gas bubbles causing the cake to rise will expand so much that they will escape from the batter. The batter will then collapse because it is too thin to entrap these much larger bubbles of gas. Thus, Boyle's Law predicts a fallen cake. To compensate, high altitude recipes suggest adding more flour to the batter to increase its viscosity. This entraps more of the carbon dioxide gas and results in a tender, fluffy cake.

In this experiment, you will vary the pressure of air contained in a syringe and measure the corresponding change in volume. You will then plot graphs of pressure versus volume and pressure versus the inverse of the volume. Review Chapter 11, Section 11.3, for further information.

Safety

Take the necessary precautions before beginning this experiment. Wear safety goggles, apron, and gloves. Read all safety cautions in your procedures and discuss them with your teacher. It is important to use good safety techniques while conducting experiments. See pages 8 through 11.

Sample Data Table

Pressure (number of weights)	Trial 1 Volume (cc)	Trial 2 Volume (cc)	Trial 3 Volume (cc)
0			
1			
2			
3			
4			

Apparatus

4 objects of equal mass (approximately 500 g each)

Boyle's law apparatus

Materials

Carpet thread

Recording Your Observations

Record your observations in a copy of the Sample Data Table that follows the procedures.

Procedures

1. Adjust the piston head so that it reads between 30 and 35 cc [redacted] Figure 9-1.

   Note: Depending on the Boyle's law apparatus that is used, you may find the volume on the syringe abbreviated in cc or cm^3. Both abbreviations stand for cubic centimeters. The apparatus pictured in Figure 12-1 is marked in cc.

   [redacted] Twist the piston several times to allow the head to overcome any frictional forces. Read the volume to the nearest 0.1 cc. Record this value as the initial volume for zero weights in your Data Table.
2. Place one of the weights on the piston. Give the piston several twists to overcome any frictional forces. When the piston comes to rest, read and record the volume to the nearest 0.1 cc.
3. Repeat Procedure 2 for two, three, and four weights.
4. Repeat Procedures 2 and 3 for at least two more trials.

Strategy for Measuring

Variables that might affect the experiment must be kept constant. The temperature of the room probably will not change during the experiment. Friction between piston head and barrel could cause heat, but will not if the procedures are carefully followed.

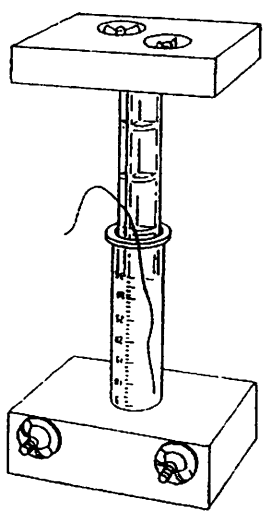

Figure 12-1

Calculations

Show your computations. Place your answers in your Calculations Table.

1. Calculate the average volumes of the three trials for weights 0–4. Record in your Calculations Table.
2. Calculate the inverse for each of the average volumes. Example: If the average volume for three weights is 26.5 cc, then $1/V = 1/26.5\ cc = 0.0377\ cc^{-1}$.

Sample Calculations Table

Pressure (number of weights)	Average Volume (cc)	$\frac{1}{\text{Volume}}$ $(\times 10^{-2})$ (cc^{-1})
0		
1		
2		
3		
4		

Strategy for Analyzing

It is often impossible to determine relationships by just looking at data in a table. A graph makes it easier to see how the variables are related. In this experiment it is necessary to plot a graph of pressure versus volume and a graph of pressure versus 1/volume before a mathematical relationship can be concluded.

Questions

1. Plot a full-page graph of pressure versus volume. Use the graph on the next page as a model. Since the number of weights added to the piston is directly proportional to the pressure applied to the gas, we can use the number of weights to represent the changes in pressure. Plot the number of weights on the horizontal axis and the adjusted volume on the vertical axis. Draw the smoothest curve that goes through most of the points. Does your graph indicate that a change in volume is directly proportional to a change in pressure? Explain.
2. Plot a full-page graph of pressure versus 1/volume. Use the below graph as a model. Plot pressure on the horizontal axis and 1/volume on the vertical axis. Draw the best line that goes through the majority of the points. What do you conclude about the mathematical relationship between pressure applied to a gas and its corresponding volume?

General Conclusions

1. Correlate the observed relationship between the pressure and volume of a gas with the kinetic theory description of a gas.
2. Use your graph to predict the volume of the gas if 2.5 weights were used.
3. If a normal sea-level recipe is used to prepare a cake 1,000 meters below the surface of the earth, the cake will be much flatter than expected. Explain and offer a solution.